Atlantic Richfield Company

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June 21, 2013

Mr. Steven Way
On-Scene Coordinator
Emergency Response Program (8EPR-SA)
U.S. EPA Region 8
1595 Wynkoop Street
Denver, CO 80202-1129

RE: **St. Louis Tunnel Discharge Ion Exchange Bench-Scale Treatability Study Work Plan**
Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01
Dolores County, Colorado

Dear Mr. Way:

On behalf of Atlantic Richfield Company (Atlantic Richfield), please find enclosed the *St. Louis Tunnel Discharge Ion Exchange Bench-Scale Treatability Study Work Plan* (Work Plan) prepared for the Rico-Argentine Mine Site (site). This Work Plan notifies the U.S. Environmental Protection Agency, Region 8, (U.S. EPA) of Atlantic Richfield's plans for conducting a treatability study to evaluate the potential of ion exchange (IX) as a potential treatment alternative or polishing step for the treatment of mine water discharging from the St. Louis Tunnel at the site. Atlantic Richfield requests U.S. EPA's approval of this Work Plan pursuant to requirements in Task F – Water Treatment System Analysis and Design / Subtask F2 – Treatment System Conceptual Designs and Additional Investigations of the Remedial Action Work Plan accompanying the Unilateral Administrative Order for Removal Action, Rico-Argentine Site, Dolores County, U.S. EPA Region 8, dated March 9, 2011 (Docket No. 08-2011-0005).

If you have any questions regarding this Work Plan, please feel free to contact me at (714) 228-6770 or via e-mail at Anthony.Brown@bp.com.

Sincerely,

Anthony R. Brown

Tony Brown
Project Manager Mining
Atlantic Richfield Company

Enclosures: *St. Louis Tunnel Discharge Ion Exchange Bench-Scale Treatability Study Work Plan*

cc: Ronald Halsey, Atlantic Richfield Company (via e-mail)
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Jan Christner, URS Operating Services, Inc. (via e-mail)

ST. LOUIS TUNNEL DISCHARGE ION EXCHANGE BENCH-SCALE TREATABILITY STUDY WORK PLAN

Rico-Argentine Mine Site – Rico Tunnels
Operable Unit OU01
Dolores County, Colorado

Prepared for:

Atlantic Richfield Company
La Palma, California

Prepared by:

AMEC Environment & Infrastructure, Inc.
Rancho Cordova, California

June 2013

Project SA11161316

amec

ST. LOUIS TUNNEL DISCHARGE
ION EXCHANGE BENCH-SCALE TREATABILITY STUDY
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LIST OF ACRONYMS

AECOM	AECOM Technical Services, Inc.
AMEC	AMEC Environment & Infrastructure, Inc.
As	arsenic
Atlantic Richfield	Atlantic Richfield Company
Cd	cadmium
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
Cu	copper
gpm	gallon per minute
IX	ion exchange
Mn	manganese
NW	northwest
Pb	lead
R&D	Research and Development
RAWP	Removal Action Work Plan
SAP	Sampling and Analysis Plan
SE	southeast
site	Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01, Dolores County, Colorado
SOP	Standard Operating Procedure
su	standard units
TSEA	Task Safety Environmental Analysis
TSHASP	Task Specific Health and Safety Plans
UAO	Unilateral Administrative Order
U.S. EPA	U.S. Environmental Protection Agency
Work Plan	St. Louis Tunnel Discharge Ion Exchange Bench-Scale Treatability Study Work Plan
Zn	zinc

ST. LOUIS TUNNEL DISCHARGE
ION EXCHANGE BENCH-SCALE TREATABILITY STUDY WORK PLAN

Rico-Argentine Mine Site – Rico Tunnels
Operable Unit OU01
Dolores County, Colorado

1.0 INTRODUCTION

This *St. Louis Tunnel Discharge Ion Exchange Bench-Scale Treatability Study Work Plan* (Work Plan) has been prepared by AMEC Environment & Infrastructure, Inc. (AMEC) on behalf of Atlantic Richfield Company (Atlantic Richfield) to describe the scope of work to be conducted to evaluate the use of ion exchange (IX) as a potential treatment alternative or polishing step for the treatment of mine water discharging from the St. Louis Tunnel at the Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01 (site). The site is located in the San Juan Mountains of southwestern Colorado, just north of the Town of Rico in Dolores County, Colorado (Figure 1). The site consists of the St. Louis Tunnel and an associated complex of underground mine workings, as well as a series of settling ponds. A general site layout is presented in Figure 2.

The activities described in this Work Plan are being conducted pursuant to the *Unilateral Administrative Order for Removal Action (UAO), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Docket No. 08-20011-0005*, effective March 23, 2011 (UAO; U.S. Environmental Protection Agency [U.S. EPA], 2011a), and the Removal Action Work Plan (RAWP) dated March 9, 2011 (U.S. EPA, 2011b), in connection with the site. This Work Plan outlines the steps to evaluate IX treatment to reduce metals loading from the St. Louis Tunnel discharge.

1.1 HEALTH, SAFETY, SECURITY, AND ENVIRONMENT EXPECTATIONS

All tasks described herein will be performed in accordance with the Task Specific Health and Safety Plans (TSHASPs) prepared by Atlantic Richfield's contractors. The appropriate risk assessments, Task Safety Environmental Analysis (TSEA), Standard Operating Procedures (SOPs), and permits will be completed prior to initiating any of the work described herein.

On-site facilities and sample locations used to evaluate IX will be located above ground. As a result, no underground work is anticipated for this task.

1.2 PROJECT TEAM, COORDINATION, AND RESPONSIBILITIES

The project team for the IX treatability study will consist of key personnel from Atlantic Richfield and their contractor personnel, as well as the U.S. EPA. The IX treatability study tasks will be conducted by Atlantic Richfield and their contractor personnel. AMEC will coordinate sampling efforts, design and implement the bench-scale IX treatability studies, and evaluate data. The bench-scale studies will be conducted by AMEC at a Research and Development (R&D) facility in Cambridge, Ontario.

2.0 BACKGROUND

The St. Louis Tunnel drains historic mine workings that extend several thousand feet into Telescope Mountain to the north and Dolores Mountain to the southeast (SE) (Figure 3). The mine workings to the northeast of the site (Pigeon, Logan, Wellington, and Mountain Springs mines) are or were hydraulically connected to the St. Louis Tunnel via the northwest (NW) Cross-cut. The workings in the southeastern portion of the site (Argentine, Blaine, Blackhawk, and other mines, collectively referred to herein as the Blaine-Argentine Mine workings) are hydraulically connected to the St. Louis Tunnel via the SE Cross-cut (Figure 3). The Blaine Tunnel and 517 Shaft provide access to the underground mine workings approximately 500 vertical feet above the St. Louis Tunnel level. As groundwater travels through the workings, oxidation of mineralized rock increases the heavy metal concentrations in the mine water. Water is ultimately discharged from the mine workings at the St. Louis Tunnel Portal and travels through a series of ponds before being released to the Dolores River.

Several sampling locations have been established at the site:

- Blaine Tunnel – This is an upgradient tunnel that is accessible from the surface at the Blaine Tunnel Portal near the tailings impoundment. The Blaine Tunnel workings drain into the St. Louis Tunnel. Flow from the Blaine Tunnel has been estimated at 25 gallons per minute (gpm) (Atlantic Richfield, 2012), but is assumed to vary seasonally. The pH of mine water from the Blaine Tunnel was in the range of 2.0 to 2.5 standard units (su) during the St. Louis Tunnel Discharge Source Mine Water Treatability Study conducted in the fall of 2012 (AMEC, 2013).

- 517 Shaft – The 517 Shaft is accessed by the 517 Shaft Access Tunnel which lies opposite the Blaine Tunnel, across Silver Creek. The 517 Shaft is the main access to the 517 Shaft workings. Mine water flowing through these workings drains into the SE Cross-cut, which flows into the St. Louis Tunnel and discharges at the St. Louis Tunnel Portal. The flow rate of mine water through the 517 Shaft cannot be directly measured, although it has been estimated at 75 gpm (Atlantic Richfield, 2012). The pH of mine water in the 517 Shaft has been measured as low as 2.7 su in October 2011 (URS, 2012) to a range of 5.9 to 6.1 su in September 2012 (AMEC, 2013).

- St. Louis Tunnel Portal – The St. Louis Tunnel Portal is the surface outlet for the mine workings that are hydraulically connected (Figures 3 and 4). A portion of the St. Louis Tunnel has collapsed at the portal; however, flow still reaches the surface from below the rubble. The flow rate from the St. Louis Tunnel Portal varies seasonally, with a pH of about 6.8 su. Based on historical data from 1973 through 2012, the flow rates at DR-3 have ranged from 265 to 2,200 gpm. The highest flow rate of 2,200 gpm was measured on August 15, 1996; the next highest flow rate was 1,403 gpm, measured on September 15, 1973. Using recent DR-3 flow data that was recorded between May 2011 and April 2012, the flow rate at DR-3 ranged from 473 to 1,007 gpm, with a time-weighted average of 755 gpm.

- AT-2 – This is an angle boring that provides access to mine water located in the St. Louis Tunnel, upgradient of the collapse at the portal. This sample location is immediately upgradient of where the discharge from the St. Louis Tunnel surfaces (Figure 4).

- DR-3 – This is a surface water sampling location immediately downgradient of the St. Louis Tunnel Portal.

- DR-3A – This is an alternate surface water sampling location downgradient of the St. Louis Tunnel Portal, but upstream of DR-3 at the historic St. Louis Tunnel Portal shed (Figure 4).

- DR-6 – This is a surface sample location near the outlet of Pond 5 (Figure 4). This sampling location is comprised of St. Louis Tunnel discharge after allowing settling through a series of ponds, immediately before discharge to the Dolores River.

The sample locations of interest for the IX bench-scale treatability study include DR-3A and DR-6, as well as effluent from the demonstration scale constructed wetland that will be constructed during the summer of 2013.

Site data indicates that although the pH of the mine water increases as it makes its way through the workings and out the St. Louis Tunnel Portal, metals concentrations are still elevated and do not meet potential surface water quality criteria for the Dolores River, which runs adjacent to the site.

2.1 Previous Ion Exchange Work

AECOM Technical Services, Inc. (AECOM) conducted initial IX evaluations in 2012 and concluded that IX should be considered further. AECOM collected site water from four sources – (1) the Blaine Tunnel, (2) the 517 Shaft, (3) sample location DR-3, and (4) sample location AT-2. Hazen Research, Inc., under subcontract to AECOM, conducted bench-scale isotherm testing of the four site waters using four IX resins. The four resins evaluated represented a range of functional group chemistries to identify the most effective resin type (Table 1). The IX resins and the functional groups evaluated were:

- Lewatit TP207 – iminodiacetate functional group;
- Purolite S950 – amino-phosphoric functional groups;
- Purolite S957 – phosphonic and sulfonic functional groups; and
- Dow XUS 43604 – thiol functional group.

The focus of the testing was on the removal of cadmium (Cd) and zinc (Zn), but arsenic (As), copper (Cu), lead (Pb), and manganese (Mn) removal was also evaluated. The results of the testing were reported in the *Ion Exchange Bench-Scale Test Results Technical Memorandum* prepared by AECOM on February 8, 2013 (AECOM, 2013) and are summarized below.

Based on a review of the AECOM results, it appears that the water from the Blaine Tunnel is not amenable to IX treatment without pretreatment to reduce acidity. Because of the additional metals loading in the mine network down gradient of the Blaine Tunnel and the 517 Shaft, including metals loading from the NW Cross-cut, treatment of flows discharging from the St. Louis Tunnel will be required regardless of treatment at the Blaine Tunnel or 517 Shaft. Therefore, Blaine Tunnel and 517 Shaft waters will not be considered further as part of the ongoing evaluation.

Purolite S957 resin shows promise as a suitable resin for the other waters tested, but the results were incomplete and preliminary, so more testing is required before that resin can be recommended. The Lewatit TP207 resin also performed well on AT-2 and 517 Shaft water, but not on DR-3 water. It is not clear why the resin performed well on AT-2, but not on DR-3, since water from those locations have a similar water quality. The performance of these two resins will be considered going forward. The Dow XUS 43604 resin performed marginally on all water tested, reducing some metals concentrations, but not as effectively as the other resins. The Purolite S950 resin performed moderately well on AT-2, DR-3, and 517 Shaft water, but not as well as the Purolite S957 and Lewatit resins. Results from this resin were also complicated due to increasing concentrations of Cu and Pb in solution during loading.

3.0 PURPOSE AND OBJECTIVES

This Work Plan describes the proposed design and implementation of a bench-scale treatability study to assess the use of IX for reducing metals loading to the Dolores River. The primary objective of the proposed work is to evaluate the cost and effectiveness of IX treatment. The specific objectives of the proposed tests are to:

- Identify IX resins that are most suitable for metals removal from the St. Louis Tunnel discharge;
- Evaluate multiple water sources to identify those that are amenable to IX treatment with the resins selected; and
- Determine the effectiveness of IX treatment for metals removal and the associated costs.

The bench-scale testing will be conducted in phases to select the IX resin(s) that are the most suitable for use at the site. A list of potential resins will be evaluated, and up to five resins will be selected for the initial isotherm (jar) tests. The most favorable resins from the isotherm tests will be subjected to additional bench-scale column testing. Bench-scale testing results will be used to evaluate the need for pilot-scale testing; the most favorable IX resins from the isotherm and column bench-scale tests may be used for pilot-scale testing. Bench- and pilot-scale testing, if conducted, will support the assessment of the potential viability of this treatment approach. IX treatability study test results from 2013 will be used to assess the feasibility of this remediation approach and form a basis for potential design and full-scale implementation of this treatment method at the site.

4.0 PROJECT OVERVIEW

To meet the treatability study objectives, AMEC has organized the proposed field work into the following three phases:

1. Bench-Scale Isotherm Testing – The initial phase will include selecting IX resins, collecting site water, and testing up to five resins using each site water sample to develop isotherms for each resin. AMEC, with input from the project team, will use the isotherms to evaluate the effectiveness of the resins and will then select the best performing resins and the best candidate water sources for additional study.
2. Bench-Scale Column Testing – Based on the results of the isotherm tests, AMEC, with input from the project team, will select several of the resins and water sources for small-scale column testing. Up to three column tests will be conducted. The column tests will establish the loading and regeneration characteristics of the selected resins to further refine the cost estimates for IX treatment.
3. Pilot Testing – If recommended based on the bench-scale studies (isotherm and column testing), AMEC will conduct an IX pilot test at the site. The scope and implementation of the pilot test will be identified in an addendum to this Work Plan, if necessary.

Specific tasks that will be completed and additional details for each of these three phases are described further in the following section. To generate data of acceptable quality that will meet the objectives of this proposed work, a Sampling and Analysis Plan (SAP) has been prepared to address the methods, sample collection and analysis. The SAP is included as Appendix A of this Work Plan. The sampling and analysis program for all phases of work is outlined in Table A-1 of the SAP.

5.0 PROJECT PHASES

This section describes the major components and rationale for each component of the three project phases.

5.1 BENCH-SCALE ISOTHERM TESTING

The bench-scale isotherm testing phase of the proposed work will consist of selecting IX resins, collecting site water, and testing. Testing will be conducted by AMEC at their R&D facility in Cambridge, Ontario. As described below, this phase will take place in two parts.

5.1.1 Resin Selection

AMEC, with input from the project team, will select up to five resins for isotherm testing. The selected resins include those that performed well in AECOM's testing and warrant further investigation, as well as resins selected by AMEC based on their functionality or their use in industrial settings with similar water chemistry. Based on previous testing, discussions with vendors, and prior experience, the resins presented in Table 2 are under consideration. Resins previously tested are presented in Table 1.

AMEC will provide resin recommendations to the project team in a technical memorandum. Recommendations will be based on the previous IX work completed, discussions with vendors, literature reviews, and information from sites using IX to treat similar waters. Once the resin selection is complete, AMEC will procure resin samples for use in the isotherm testing.

5.1.2 Site Waters To Be Tested

AMEC will procure water from the site for bench-scale testing and ship it to the R&D facility in Cambridge, Ontario. It is expected that water will be collected in plastic containers with no headspace; however, AMEC personnel will direct the quantity of water required and the preferred storage and preservation methods to maintain testing integrity.

Previous IX testing has shown that the Blaine Tunnel water is not amenable to IX treatment (AECOM, 2013). In addition, further investigation of the Blaine Tunnel water and 517 Shaft water is not warranted, since treatment of the St. Louis Tunnel discharge would still be required. As a result, this treatability study is focused on treatment of the St. Louis Tunnel discharge. Testing will be conducted using the following three water sources:

1. DR-3A prior to the 517 Shaft injection test[1];
2. DR-3A during the 517 Shaft injection test; and
3. Wetland Demonstration effluent after colonization and completion of the 517 Shaft injection test[2].

These sample locations were selected to evaluate the effectiveness of (1) IX for treatment of untreated water from the St. Louis Tunnel discharge, (2) IX treatment in series with injection of alkaline solutions to the 517 Shaft, or (3) IX as a polishing treatment method for constructed wetland effluent. Additionally, a bulk water sample will be taken at DR-6 prior to the 517 Shaft injection test for optional bench-scale testing to evaluate the effects of pond settling on IX performance.

Because the water samples for bench-scale testing will be collected before and during the 517 Shaft injection test, as well as after construction and colonization of the demonstration scale wetland, bulk water sampling the sampling tasks and bench-scale testing will occur in three phases, as described in Section 6.0.

5.1.3 Isotherm Testing

All materials and supplies, including resins and site water, will be shipped to and received by AMEC at the R&D facility in Cambridge, Ontario. AMEC will design and conduct jar testing (also called isotherm tests), consisting of agitating a known quantity of water and resin in a jar and periodically sampling the water. Samples will be collected and screened for As, Cd, Cu, Fe, Mn, Pb, Zn and pH as described in the SAP (Appendix A). AMEC will then generate isotherms to evaluate metals removal from each water source.

Each of the three water samples listed in Section 5.1.2 will be subjected to isotherm testing with up to five IX resins (i.e., up to 15 isotherm tests will be conducted). The results of the isotherm tests will be used to identify resin effectiveness and to select candidate water sources for possible further testing. The isotherms will also identify resin loading

[1] The geochemistry of mine water at DR-3 will be altered during the injection of alkaline solutions. The injection test for 2013 is described by Atlantic Richfield (2013).
[2] Construction and startup of wetland demonstration system is planned for summer of 2013.

characteristics and will help establish the suitability of each resin tested for metals removal. Based on the results of this work, IX may be evaluated as a stand-alone treatment system, as a unit process in part of a larger treatment system, or as a polishing step following primary treatment.

5.2 BENCH-SCALE COLUMN TESTING

Based on the results of the isotherm tests, AMEC, with input from the project team, will select the best performing resins and water sources for column testing. The purpose of the column testing is to establish the number of bed volumes required to achieve breakthrough and to establish how efficiently and effectively the resins are regenerated. These characteristics will be used to establish cost estimates for IX treatment. Specific column testing tasks are detailed below.

5.2.1 Resins and Water Source Selection

AMEC will use the results of the isotherm testing to identify resins and water sources that should be evaluated further. Selections will be made primarily on the overall metals removal performance. AMEC anticipates that up to three column tests will be run, although additional column testing may be requested based on the isotherm testing data.

The bulk water sample taken from DR-3A before the start of the 517 Injection test will be used for column testing. The other two samples (DR-3A during the injection test and effluent from the demonstration scale constructed wetland system) may be used for column testing, depending on the results of isotherm tests. Decisions on column testing will be made in consultation with the project team.

5.2.2 Column Testing

The goal of this phase of the study is to evaluate the resin capacity and regeneration capabilities. AMEC will design and perform the column tests. AMEC will procure or fabricate all equipment and materials (e.g., resins, columns, fittings, etc.) except site water. AMEC may collect additional water from the site, if necessary to complete the column testing.

The design of the column is very important at this stage, since the test must mimic full-scale loading rates, but have a small enough volume of resin to achieve breakthrough in a reasonable time. AMEC, with input from the project team, will design the small-scale column tests based on standard procedures (described in SOP 12.0, included with Appendix A). AMEC will fill a small column with resin and elute site water through the column until they achieve breakthrough. Samples will be collected throughout the column tests to evaluate loading kinetics. All sampling and analyses will be conducted according to the SAP included in Appendix A. Once breakthrough is achieved, the resin will be regenerated, and the column breakthrough test will be repeated once. The resin will be fully loaded and regenerated twice to ensure there are no resin-poisoning constituents that might prevent proper long-term operation.

5.3 PILOT TESTING

A pilot study may be recommended based on the results of the bench-tests. The purpose of the pilot study would be to operate a larger-scale system with a larger volume of resin to evaluate loading, breakthrough, and regeneration under conditions at the site. The results of the pilot study would be used to further refine costs and operating requirements by treating a small portion of the flow with on-site equipment. If recommended, the details of the pilot study will be identified in an addendum to this Work Plan.

6.0 IMPLEMENTATION SCHEDULE

All work described herein will be initiated and completed upon U.S. EPA approval. Additionally, all work activities will have to be implemented in coordination with other site activities, in particular the 517 Shaft injection test. Therefore, the estimated general schedule for the IX treatability study is as follows:

- Phase 1, Bench-Scale Isotherm Testing: will occur in three rounds, corresponding to the three rounds of bulk water sampling. Each round of isotherm testing will start shortly after sample collection, and each round will take approximately one week.

    1. The first round of isotherm testing will use water from DR-3A that is not impacted by the 517 Shaft injection test. This bulk water sample will be collected in June, 2013 before injection of alkaline solutions to the 517 Shaft.

    2. The second round of isotherm testing will use water from DR-3A that is altered by the 517 Shaft injection test. This bulk water sample will likely be collected in July, 2013, after the 517 Shaft injection test has approached a steady-state condition.

    3. The third round of isotherm testing will use effluent from the demonstration scale constructed wetland. This bulk water sample will be collected after startup and colonization of the constructed wetland system, likely in October or November, 2013.

- Phase 2, Bench-Scale Column Testing: Each column test is anticipated to have a duration of 15 to 20 days; multiple column tests may be run concurrently. Column test duration will depend on water quality characteristics and the column design (e.g., each column test must achieve breakthrough twice to be complete).

1. Column testing with DR-3A water that is not impacted by the 517 Shaft injection test will occur after resins have been screened using isotherm testing on water collected in June, 2013. These column test(s) will likely be completed by July or August, 2013.

2. Additional column tests may conducted after isotherm testing of the other water samples (DR-3A during the injection test, and demonstration scale constructed wetland effluent). Completion of these column tests is anticipated by December, 2013.

- Phase 3, Pilot Testing: if conducted, the timing of on-site pilot testing depends on the water source used. If the water source requires ongoing 517 Shaft injection, testing would start before the 517 Shaft injection test completion date in late September, 2013. Rather than extend the duration of the 517 Shaft injection test to accommodate IX pilot testing, water treated by the 517 Shaft injection test could be stored in tanks on-site for the IX pilot test. If the water source is one that is not impacted by the 517 Shaft injection test, IX pilot testing could start after injection testing is complete and post injection monitoring indicates acceptable conditions for pilot testing.

Implementation of the bench-scale studies is anticipated to be complete by the middle of December 2013. AMEC, with input from the project team, will determine if pilot testing will be conducted. Details of the pilot testing duration and operations would also be determined at that time. These dates are subject to change based on actual field implementation times and weather conditions that may cause delays.

7.0 DATA COLLECTION

The data collection described in this Work Plan will include sampling and analysis and the measurement of water quality parameters and metals concentrations before, during, and after bench-scale studies. Data collected will be evaluated to determine the effectiveness of IX for several site water sources as a stand-alone treatment step, as a unit process treatment step, or as a polishing treatment step.

Sample and data collection will be governed by the task-specific SAP (Appendix A). The SAP is specific to the activities that are described in this Work Plan and includes the Field Sampling Plan, a Quality Assurance Project Plan, and related SOPs. The SAP provides guidance for field and laboratory activities, data collection activities, and sample analysis activities so that the data will meet the objectives of the treatability study. The SOPs are an integral part of the SAP and establish the procedures, equipment, and documentation that will be used during the treatability study sampling and measurement activities.

8.0 REPORTING

Test results will be communicated via two mechanisms: (1) regular communications with the project team via teleconference or email during the bench testing; and (2) preparation of an IX bench-scale treatability study report with details and interpretation of test results. The communication will convey the following information:

- The resins identified for testing and the reasons they were selected;
- The suitability of each resin for metals removal from site waters;
- The loading, breakthrough, and regeneration characteristics of the resins tested; and
- The recommended resins for additional testing or use at the site and the basis for those recommendations.

During the bench testing, regular conference calls will be conducted to discuss implementation issues, status of testing, and interim results. Additional calls may be conducted, as necessary, to keep the project team informed of progress and to work through issues that may arise. Key personnel from Atlantic Richfield and U.S. EPA will be invited to participate in these calls.

After the conclusion of the bench tests and finalization of all data, a final IX treatability study report will be prepared and submitted to the U.S. EPA. The report will include a comprehensive description of the treatability study, including a description of the methodology, any deviations from this Work Plan, results of all monitoring and analytical data, and an interpretation of those results. Data collected will be evaluated to determine the effectiveness of IX resins to reduce metals loading from the St. Louis Tunnel discharge. Recommendations for future actions, potentially including a pilot study to be conducted at the site, will be presented.

9.0 REFERENCES

AECOM, 2013, Ion Exchange Bench-Scale Test Results, Rico-Argentine Mine Site, Rico, Colorado, submitted to Atlantic Richfield Company, February 8.

AMEC, 2013. St. Louis Tunnel Discharge Source Mine Water Treatability Study Completion Report, in preparation for Atlantic Richfield Company, June 2013.

Atlantic Richfield, 2012. St. Louis Tunnel Discharge Source Mine Water Treatability Study Work Plan. Rico-Argentine Mine Site, Dolores County, Colorado. August 30, revised October 4. (prepared by AMEC Environmental & Infrastructure, Inc.)

URS, 2012, 2011 Source Water Investigation Report, Rico-Argentine St. Louis Tunnel, Rico, Dolores County, Colorado, March 20, 2012.

U.S. EPA, 2011a, Unilateral Administrative Order for Removal Action (UAO), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Docket No. 08-20011-0005, March 23, 2011.

U.S. EPA, 2011b, Removal Action Work Plan Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01 Rico, Colorado, EPA Region 8, for Atlantic Richfield Company, March 9, 2011.

TABLES

TABLE 1
RESINS PREVIOUSLY EVALUATED
ION EXCHANGE BENCH-SCALE TREATABILITY STUDY WORK PLAN
Rico-Argentine Mine Site
Dolores County, Colorado

Resin	Class	Functional Group/Type	Ionic Form	Selectivity	Primary Application
Purolite S950	Chelating	Amino-phosphoric acid	Na^+	**Acidic pH:** $H^+ > Fe^{3+} > Pb^{2+} > Cu^{2+} > Zn^{2+}, Al^{3+} > Mg^{2+} > Ca^{2+} > Cd^{2+} > Ni^{2+} > Co^{2+} > Na^+$ **Alkaline pH:** $Cd^{2+}, Mg^{2+} > Ca^{2+} > Sr^{2+}, Al^{3+} > Ba^{2+} >> Na^+, K^+$	Designed for removal of toxic metals (lead, copper, zinc) at low pH
Dow XUS 43604	Chelating	Thiol	Not available	Highly selective for mercury capture, and platinum group metals	Separation of mercury liquid media
Lewatit MonoPlus TP 207	Weak Acid Cation with Chelating Groups	Iminodiacetic	Na^+	$Cu > V > UO_2 > Pb > Ni > Zn > Cd > Fe(II) > Be > Mn > Ca > Mg > Sr > Ba >>> Na$	For selective extraction of heavy metal cations from weakly acidic to weakly basic solutions, even in the presence of high calcium concentrations
Purolite S957	Chelating	Phosphonic/Sulfonic	H^+	Not available	For removal of iron from acidic solutions

TABLE 2
POTENTIAL RESINS TO EVALUATE
ION EXCHANGE BENCH-SCALE TREATABILITY STUDY WORK PLAN
Rico-Argentine Mine Site
Dolores County, Colorado

Resin	Class	Functional Group/Type	Ionic Form	Selectivity	Primary Application
Purolite C104 in Ca-Form	Weak Acid Cation	Polyacrylic	Ca^{2+}	Not available	Dealkalization and deionization; used in all types of demineralization where regeneration efficiency and high operating capacity are needed
Purolite S930 Plus	Chelating	Iminodiacetic	Na^{+} (pH 2-6), H^{+} (pH 6-11), or Ca^{2+}	Cu >> Ni > Zn^{3}, Co^{3}, Cd > Fe(II) > Mn > Ca	Heavy metals/brine decalcification/copper and base metals
Purolite S957	Chelating	Phosphonic/Sulfonic	H^{+}	Not available	For removal of iron and other transitional metals from acidic solutions
Lewatit MonoPlus TP 207	Weak Acid Cation with Chelating Groups	Iminodiacetic	Na^{+}	Cu > V > UO_2 > Pb > Ni > Zn > Cd > Fe(II) > Be > Mn > Ca > Mg > Sr > Ba >>> Na	For selective extraction of heavy metal cations from weakly acidic to weakly basic solutions, even in the presence of high calcium concentrations
Dow DOWEX G-26	Strong Acid Cation	Sulfonic Acid	H^{+} or Ca^{2+}	Not Available	Specialty demineralization and catalyst applications
Dow (Rohm and Haas) AMBERLYST 15WET	Strong Acid Cation	Sulfonic Acid	H^{+}	Not Available	Removal of metal impurities in chemical processing applications
Siemens SCU	Carbonaceous Absorbent	Absorptive Media, not Resin	Ca^{2+}	Not Available	Absorption of transition metals from industrial wastewater, ground water, and storm water
ResinTech SIR-300	Weak Acid Cation with Chelating Groups	Iminodiacetic	Na^{+}	H^{+} > Cu > V >> UO_2 > Pb > Ni > Zn > Co > Cd > Fe(II) > Be > Mn > Mg > Ca > Sr > Ba >> Na **High Chloride Solutions:** $Cu^{2+} > Ni^{2+} > Co^{2+} > Zn^{2+} > Cd^{2+} > Fe2^{+}$ **High Sulfate Solutions:** $Cu^{2+} > Ni^{2+} > Cd^{2+} > Zn^{2+} > Co^{2+} > Fe^{2+}$	Removal of heavy metal ions even against high concentrations of calcium

FIGURES

0 2.5 5 10 15 20
Miles

SITE LOCATION MAP
Rico-Argentine Mine Site
Dolores County, Colorado

By: dpv	Date: 05/31/2013	Project No. SA11161316
amec		Figure 1

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SITE LAYOUT
Rico-Argentine Mine Site
Dolores County, Colorado

By: dpv	Date: 05/31/2013	SA11161316
amec		Figure 2

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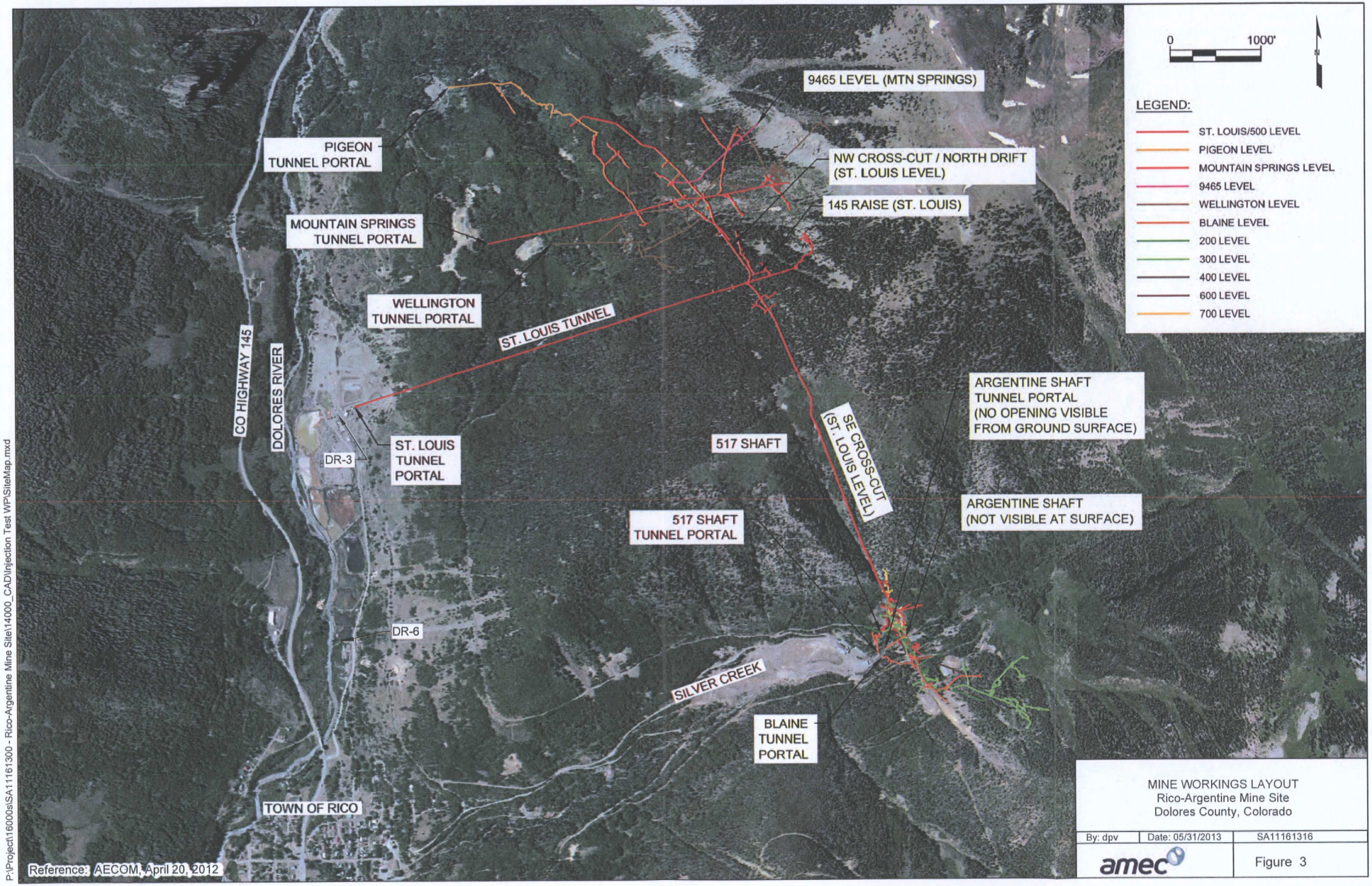

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POND LAYOUT
Rico-Argentine Mine Site
Dolores County, Colorado

By: dpv	Date: 06/19/2013	Project No. SA11161316
amec		Figure 4

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APPENDIX A

Sampling and Analysis Plan

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APPENDIX A
SAMPLING AND ANALYSIS PLAN
ST. LOUIS TUNNEL DISCHARGE
ION EXCHANGE BENCH-SCALE TREATABILITY STUDY
WORK PLAN

Rico-Argentine Mine Site – Rico Tunnels
Operable Unit OU01
Dolores County, Colorado

Prepared for:
Atlantic Richfield
La Palma, California

Prepared by:
AMEC Environment & Infrastructure, Inc.
Rancho Cordova, California

June 2013

Project No. SA11161316

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APPENDIX A: SAMPLING AND ANALYSIS PLAN
ST. LOUIS TUNNEL DISCHARGE ION EXCHANGE BENCH-SCALE TREATABILITY STUDY WORK PLAN

Rico-Argentine Mine Site – Rico Tunnels,
Operable Unit OU01
Dolores County, Colorado

1.0 INTRODUCTION

This Task-Specific Sampling and Analysis Plan (SAP) has been prepared by AMEC Environment & Infrastructure, Inc. (AMEC), on behalf of the Atlantic Richfield Company (Atlantic Richfield), for the St. Louis Tunnel Discharge Ion Exchange Bench-Scale Treatability Study. This study is being conducted to evaluate the use of ion exchange (IX) as a potential treatment alternative or polishing step for the treatment of mine water discharging from the St. Louis Tunnel, as described in the main body of the *St. Louis Tunnel Discharge Ion Exchange Bench-Scale Treatability Study Work Plan* (Work Plan). Such evaluations are integral in completion of Task F- Water Treatment system Analysis and Design described in the Removal Action Work Plan (U.S. EPA, 2011a) for the site.

1.1 PURPOSE

This task-specific SAP provides guidance for the sample collection, laboratory analyses and bench-scale testing activities that are described in the Work Plan. It also ensures that the sampling and data collection activities will meet the objectives for evaluating future treatment options. This SAP discusses the procedures for field sampling and data collection activities, for conducting experimental testing, and for performing laboratory analytical testing to complete the bench-scale treatability study tasks.

This task-specific SAP has a limited scope and has been prepared to fulfill the objectives of the Work Plan. This SAP includes a Field Sampling Plan (FSP), a Quality Assurance Project Plan (QAPP), and Standard Operating Procedures (SOPs) for all field activities that will be used to collect samples, measure water quality parameters, conduct bench-scale treatability testing, and generate data for evaluation of the bench-scale treatability study. This SAP and its components are therefore task-specific for the described bench-scale treatability study. The FSP is included as Section 3 of this SAP and provides guidance for the fieldwork that will be used to complete the tasks and objectives as defined within the Work Plan. The St. Louis Tunnel Discharge Source Mine Water Treatability Study QAPP, Rico-Argentine Mine Site – Rico Tunnels (Atlantic Richfield, 2013) previously submitted to the U.S. EPA establishes the policy, organization, functional activities, quality assurance and quality control (QA/QC) protocols, and SOPs that provide the necessary guidance for procedures, equipment, and documentation that will be used during the sampling, testing, and measurement activities and are incorporated herein by reference in this SAP. Additional details for the planned bench-scale experiments are provided in SOP 12.0 (included as Attachment 1) which supplements the existing set of treatability study SOPs for this task-specific SAP.

1.2 HEALTH, SAFETY, SECURITY, AND ENVIRONMENT (HSSE) EXPECTATIONS

All sampling and analysis activities as described in this SAP will be performed in accordance with the Task Specific Health and Safety Plans prepared by AMEC and their subcontractors. The appropriate risk assessment, health and safety SOPs, and permits will be completed prior to initiating any work described herein.

2.0 OBJECTIVES AND SCOPE

2.1 OBJECTIVES

The objectives of this SAP are as follows:

- Provide guidance for field and experimental testing activities, data collection activities, and sample analysis activities so that the results will meet the objectives and tasks of the bench-scale treatability study;
- Ensure that sampling and data collection activities will be comparable to and compatible with previous data collection activities; and
- Provide a mechanism for planning and approving field activities.

The objectives of the IX bench-scale treatability study are described in Section 3 of the Work Plan. The results of this work will be used to evaluate the feasibility of this remediation approach and to form a basis for potential design and full-scale implementation of IX as a treatment method at the site.

2.2 SCOPE

This task-specific SAP describes the sampling and measurement methods for the bench-scale treatability study as described in the Work Plan. The study will include sample collection to provide site water for jar tests (isotherm tests) and column tests, collectively referred to as IX bench-scale testing, characterization testing, and efficiency testing. Prior to IX testing, water samples will be collected and analyzed for total and dissolved metals and other general water quality parameters as described in Table A-1. During the IX testing, water samples will be monitored for pH and temperature. Samples subjected to IX experiments will be submitted for total and dissolved metals analyses to provide data to evaluate efficiency of IX for reducing metals loading in mine water discharging from the St. Louis Tunnel.

3.0 FIELD SAMPLING PLAN

This section presents the FSP for the IX bench-scale treatability study. The IX bench-scale treatability study will include the following sampling phases:

1. Bulk water sampling. Bulk water samples will be collected by AMEC for use in the bench-scale testing. Field measurements will be collected concurrent with sample collection and samples will be submitted for laboratory testing to aid in establishing water quality prior to commencement of any IX experiments as outlined in Table A-1.

2. IX bench-scale testing. AMEC will conduct bench-scale tests that include jar testing and column testing. Water samples will be collected throughout the various phases of testing and analyzed at an analytical laboratory as outlined in Table A-1.

Table A-1 summarizes the water samples and field measurements that are to be collected by location, and Table A-2 summarizes the methods, holding times, and preservation requirements for all samples and water quality measurements. The details for conducting IX bench-scale testing are provided in SOP 12.0 (Attachment 1).

3.1 SAMPLE LOCATIONS

Samples will be obtained and water quality parameters will be measured at three locations – (1) DR-3A, (2) DR-6, and (3) the Demonstration Wetland system effluent. Sample aliquots will also be collected following bench-scale testing conducted by AMEC.

3.2 FIELD ACTIVITIES AND SAMPLING

The following sections describe the sampling methods that will be used.

3.2.1 Bulk Water Samples

Bulk water samples will be collected by AMEC for use in the bench-scale tests. During sample collection, field parameters will be measured. At each location, a calibrated water quality meter will be placed in the water stream to measure the water quality parameters (pH, temperature, specific electrical conductance, etc.). The flow rate at DR-3A and the wetland demonstration effluent will be measured using the existing/anticipated instrumentation. Water samples will be collected for laboratory analysis as outlined in Table A-1 using the U.S. EPA approved methods provided in Table A-2.

3.2.2 Bench-Scale Testing

This phase includes jar tests and column tests that will be conducted by AMEC using site water. The procedures for bench-scale testing are provided in SOP 12.0 (Attachment 1). Samples collected during the bench tests will be used to judge the effectiveness of IX.

Samples will be collected from the jar and column tests at intervals specified in Table A-1. Samples will be submitted for total and dissolved metals analysis (Table A-2) to ALS Global in Waterloo, Ontario. In addition, split samples will be sent for confirmation testing to Pace Analytical in Lenexa, Kansas at a frequency of ten percent of the total samples tested. Water quality parameters (pH) and temperature will be measured during IX testing using a properly calibrated water quality meter.

3.3 WATER QUALITY PARAMETER MEASUREMENTS

The following parameters will be measured in the field with calibrated field instrumentation as summarized in Table A-1:

- pH;
- Specific electrical conductance;
- Temperature;
- Oxidation reduction potential (ORP); and
- Dissolved oxygen (DO).

Additionally, the flow rate will be measured at the DR-3 using the existing flow measurement devices. SOPs for calibrating field instruments and measuring field parameters and flow rates are provided in the referenced QAPP (Atlantic Richfield, 2013).

3.4 LABORATORY ANALYTICAL METHODS

Table A-2 summarizes the laboratory analytical methods that will be used for each parameter, and the referenced QAPP (Atlantic Richfield, 2013) further describes the laboratory QA/QC requirements for these analyses.

3.5 SAMPLE DESIGNATIONS

The unique sample designations to be used during the treatability study are defined in this section. To maintain organization of data, sample identification numbers will include a sample location identifier. The sample date and time will also be recorded. Location Identifiers for samples will be as follows:

DR-3A – Location identifier is "DR3A".

DR-6 –Location identifier is "DR6".

Wetland Demonstration Effluent – Location identifier is "RDEFF".

As an example, a sample taken on May 21, 2013 from DR-3A will be designated as "DR3A130521.

Sample containers will be labeled with self-adhesive labels, with all necessary information filled out using waterproof ink. At a minimum, each sample label will contain the following information:

- project name;
- site location;
- sample identification code;
- date and time of sample collection, with sampler's initials;
- analyses required;
- method of preservation, if used; and
- sampler's initials.

3.6 SAMPLE HANDLING

The field sample handling and analysis procedures are described in the SOPs, included in Attachment A-1 of the referenced QAPP (Atlantic Richfield, 2013) and are incorporated herein by reference. Examples of paperwork included in the respective SOPs include chain-of-custody forms, sample logs, and sample labels. Table A-2 identifies the required sample volumes, sample preservation methods, types of sample containers, packing and shipping requirements, sample designation requirements for the project database, documentation requirements, and holding times for the planned sample analyses. Additional sample handling requirements are given in SOP 12.0 (Attachment 1) and are specific to samples collected during IX testing.

4.0 QUALITY ASSURANCE PROJECT PLAN

Atlantic Richfield's St. Louis Tunnel Discharge Source Mine Water Treatability Study QAPP (Atlantic Richfield, 2013) provides the basis for a more directed and logical QA/QC process for short-term environmental data collection activities associated with source mine water treatability studies and treatment option evaluations through treatability and/or bench-scale testing. Such short term data collection programs are designed to properly collect and evaluate screening and/or definitive data in a limited amount of time without the constraints of a rigorous QA/QC program. For this bench-scale treatability study, the sampling and analysis activities conducted by AMEC will be in general accordance with these procedures.

AMEC has developed task-specific SOPs (Attachment A-1 of the referenced QAPP (Atlantic Richfield, 2013) to describe field procedures for collecting samples for testing purposes and performing field measurements. Table A-1 summarizes sample collection and analyses to be employed. Mine water samples collected from the site will be sent to AMEC in Cambridge, Ontario via a refrigerated transport vehicle to maintain appropriate sample temperature. Water samples generated from the bench testing will be collected and sent to ALS Laboratory in Waterloo, Ontario (ALS) and analyzed for total and dissolved metals as outlined in Table A-1. ALS is accredited by the Canadian Association for Laboratory Accreditation, Inc. (CALA). The ALS Quality Assurance Manual, prepared in accordance with EPA Requirements for Quality Management Plans (QA/R-2), EPA/240/B-01/002 (U.S EPA, 2011b), is maintained in the project files and is available upon request.

Split samples will also be collected concurrently (at a frequency of ten percent) and sent to Pace Analytical Lab (Pace) in Lenexa, Kansas for confirmation analyses. Pace is an accredited environmental testing laboratory through the National Environmental Laboratory Accreditation Program (Kansas NELAP Certificate No. E-101116). Pace will adhere to the additional quality control requirements set forth in Atlantic Richfield's Technical Requirements for Environmental Laboratory Services (Atlantic Richfield, 2011b), which provides quality standards for contracted laboratories performing work for Atlantic Richfield. All samples will be submitted to the respective laboratories using proper chain of custody procedures and will be analyzed using the U.S. EPA approved methodologies presented in Table A-2.

Results for field measurements will be checked for completeness and accuracy as described in the referenced QAPP (Atlantic Richfield, 2013). Laboratory results will be provided to AMEC for data verification and evaluation to ensure all data meet the requirements of the LaMP (Atlantic Richfield, 2011). A relational database using Microsoft Access® software will be maintained with field and laboratory analytical measurements.

5.0 STANDARD OPERATING PROCEDURES

The SOPs establish the procedures, equipment, and documentation that will be used during the field sampling, field instrument calibration, and water quality measurements activities for the IX bench-scale treatability study are included in Attachment A-1 of the referenced QAPP (Atlantic Richfield, 2012) and are incorporated herein by reference. These SOPs cover aspects of the bench-scale treatability study related to sampling, sample handling, documentation, and field measurement methods.

For experimental procedures specific to IX bench testing, SOP 12.0 has been developed to supplement the existing set of SOPs established for treatability studies. Together, these SOPs will be followed during field sampling and bench-scale testing to ensure that all activities are completed consistently and properly documented.

All field personnel will have access to the most recent versions of the field SOPs. Revisions to SOPs are documented in accordance with the referenced QAPP (Atlantic Richfield, 2013). Project files will be updated accordingly with the most recent versions.

6.0 REFERENCES

Atlantic Richfield, 2011. Technical Requirements for Environmental Laboratory Services - BP Laboratory Management Program, Revision 10. December.

Atlantic Richfield, 2013. St. Louis Tunnel Discharge Source Mine Water Treatability Study Quality Assurance Project Plan. Rico-Argentine Mine Site – Rico Tunnels Operable Unit OU01, Dolores County, Colorado. Revision 0, June 2013. (prepared by AMEC Environmental & Infrastructure, Inc.)

United States Environmental Protection Agency (U.S. EPA), 2001, EPA Requirements for Quality Management Plans (QA/R-2) EPA/240/B-01/002, March.

United States Environmental Protection Agency (U.S. EPA), 2011a, Removal Action Work Plan Rico-Argentine Mine Site – Rico Tunnels, Operable Unit OU01 Rico, Colorado, EPA Region 8, for Atlantic Richfield Company, March 9, 2011.

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TABLES

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TABLE A-1
FIELD SAMPLING PLAN SUMMARY
ION EXCHANGE BENCH-SCALE TREATABILITY STUDY SAMPLING AND ANALYSIS PLAN
Rico-Argentine Mine Site
Dolores County, Colorado

Phase	Sample Location and Timing	Estimated Duration (days)	Sample Frequency	Estimated Number of Samples	Sampling Method	Analyses	Rationale
Bulk Water Sampling	DR-3A (Pre-Injection)	1	1 sample	1	Grab	Water Quality Parameters (1); Lab (2)	Collect water for characterization and bench-scale testing
	DR-3A (During Injection)	1	1 sample	1	Grab	Water Quality Parameters (1); Lab (2)	Collect water for characterization and bench-scale testing
	RDEFF (After Injection)	1	1 sample	1	Grab	Water Quality Parameters (1); Lab (2)	Collect water for characterization and bench-scale testing
	DR-6 (5)	1	1 sample	1	Grab	Water Quality Parameters (1); Lab (2)	Collect water for characterization and possible bench-scale testing
Laboratory Isotherm Testing (Jar Tests)	DR-3A (Pre-Injection)	1*	Approximately 15 minutes, 30 minutes, 1.5 hours, and 4 hours*	4 per resin	Grab	pH; temperature; Lab (3)	Assess resin effectiveness for specific water
	DR-3A (During Injection)	1*	Approximately 15 minutes, 30 minutes, 1.5 hours, and 4 hours*	4 per resin	Grab	pH; temperature; Lab (3)	Assess resin effectiveness for specific water
	RDEFF (After Injection)	1*	Approximately 15 minutes, 30 minutes, 1.5 hours, and 4 hours*	4 per resin	Grab	pH; temperature; Lab (3)	Assess resin effectiveness for specific water
Small-scale Laboratory Column Tests	DR-3A (Pre-Injection)	15-20*	Approximately 1 sample per day*	20 per resin (4)	Grab	pH; temperature; Lab (3)	Assess resin capacity & regeneration characteristics
	DR-3A (During Injection)	15-20*	Approximately 1 sample per day*	20 per resin (4)	Grab	pH; temperature; Lab (3)	Assess resin capacity & regeneration characteristics
	RDEFF (After Injection)	15-20*	Approximately 1 sample per day*	20 per resin (4)	Grab	pH; temperature; Lab (3)	Assess resin capacity & regeneration characteristics

Notes/Abbreviations:
* – sample frequencies and/or test durations are estimated and may be adjusted, if required to obtain acceptable data for isotherm or column tests.
(1) Water quality parameters consist of pH, temperature, specific electrical conductance, ORP, and DO using calibrated instrumentation.
(2) Lab analyses for bulk samples: total dissolved solids; total suspended solids; alkalinity; hardness; total sulfate; cyanide; total and dissolved metals (As, Cd, Cu, Fe, Pb, Mn, Zn by EPA 200.8). See Table A-2 for analytical methods.
(3) Lab analyses: total and dissolved As, Cd, Cu, Fe, Mn, Pb, and Zn (EPA 200.8).
(4) Column testing will be conducted on select water & resin combinations based on the results of the isotherm tests. Up to four column tests (total) are planned.
Samples will be collected every 4-5 bed volumes, but about
(5) Water will be collected from DR-6 and held in the event that bench-scale testing is determined appropriate.

DO = dissolved oxygen
ORP = oxidation reduction potential
RDEFF = Rock Drain Effluent sampling location, which is
SEC = specific electrical conductance

TABLE A-2
METHODS, HOLDING TIMES, AND PRESERVATION REQUIREMENTS
ION EXCHANGE BENCH-SCALE TREATABILITY STUDY SAMPLING AND ANALYSIS PLAN
Rico-Argentine Mine Site
Dolores County, Colorado

Parameter	Method Reference	Container	Suggested Volume[1]	Preservation[2]	Estimated Detection Limit	Maximum Holding Time
Bench Scale Treatability Testing						
Ion Exchange Test	SOP 12.0	P	80 L[4]	No headspace;	Not applicable	Not applicable
Laboratory Analyses						
Total and Dissolved Metals[3]	EPA 200.8	P	500 mL	HNO_3 to pH<2; Field filtered for dissolved metals	0.5 - 50 ug/L	6 months
Hardness	SM 2340B	P	100 mL	HNO_3 to pH<2	2 mg/L	6 months
Alkalinity	SM 2320B	P	250 mL	None	20 mg/L	14 days
Sulfate	EPA 300.0	P	100 mL	None	1 mg/L	28 days
Cyanide	SM 4500CN	P	250 mL	NaOH to pH>12	5 ug/L	14 days
Total Dissolved Solids	SM 2540C	P	250 mL	None	5 mg/L	7 days
Total Suspended Solids	SM 2540D	P	250 mL	None	5 mg/L	7 days
Field Measurements						
Flow Rate	SOP 6.0	P	N/A	None	0.1 feet/second	None
pH	SOP 3.0	P	100 mL	None	0.1 unit	15 minutes
Conductivity					0.1 µS/cm	15 minutes
Temperature					0.15 °C	15 minutes
Oxidation Reduction Potential					0.1 mV	15 minutes
Dissolved Oxygen					0.2 mg/L	15 minutes

Notes/Abbreviations:
1 - Additional volume may be provided for laboratory QC samples (e.g., matrix spike, laboratory duplicate).
2 - Samples should be stored at a temperature ranging from 0°C - 6°C, or analyzed immediately.
3 - Metals: As, Cd, Cu, Fe, Mn, Pb, and Zn (EPA 200.8)
4 - Volume requirements for column testing will require an additional 400L after initial isotherm jar tests are concluded.
P = Polyethylene

ATTACHMENT 1

Standard Operating Procedures

1.0 – ION EXCHANGE BENCH-SCALE TESTING

Purpose and Scope: This document outlines the experimental procedures to be employed in testing the effectiveness of different ion exchange resins for the treatment of mine wastewater from the Rico-Argentine Mine Site. The following procedures for column testing are based on published methods (ASTM D3375 & ASTM D2187). The procedure for isotherm (jar) testing has been adapted from instructions provided by the manufacturer (DOWEX).

1.1 ISOTHERM TESTING

Apparatus: The following equipment will be required to complete the isotherm testing:

- 4, 1-litre beakers per water sample and resin combination
- Bench mixing apparatus
- Nitrile gloves as required
- Temperature probe
- pH meter
- Laboratory containers for sample analysis
- Notebook and spreadsheet software for data recording and analysis

Procedure: The following procedure will be followed in testing each resin and source water combination. All resins will be preconditioned per the manufacturer's specifications.

1. For each resin and source water combination, 4 1-litre beakers will be prepared with labels indicating 15 minutes, 30 minutes, 1.5 hours and 4 hours.
2. Water will be added to the beakers, followed by resin. The ratio of water to resin will be determined by the manufacturer instructions. The resin will be washed and preconditioned per the specifications.
3. The beakers will be placed in a mixing apparatus and mixed continuously at low speed for up to 4 hours.
4. A water sample will be collected from each final solution, preserved appropriately, and submitted for laboratory analysis.
5. Water samples will be monitored for temperature and pH during the experiments. .
6. The above procedure will be repeated for each combination of selected resins and water source.
7. Two control tests will also be performed. A procedural control test will be performed by washing and preconditioning the resin, and performing a test using deionized water. An analytical control test will be performed using mine water without resin, under test conditions. Steps 1 through 5 will be repeated for each control test.

1.2 Column Testing

Apparatus: The following equipment will be required to complete the column test:

- Nitrile gloves as required
- A transparent, vertically supported column with an inside diameter of 25.4 m (1 in.) and a height of approximately 1500 mm (60 in.).
- Supporting material (glass beads) for the ion exchange resin
- 6-mm tubing
- A peristaltic pump
- 6 6-mm valves to allow for control of flow and backwash
- Deionized water
- Acid reagent, as suggested by the manufacturer
- Laboratory containers for sample analysis
- Temperature probe
- pH meter

Procedure: The following procedure will be followed in testing each resin and water source.

1. The temperature of the source water, deionized water, and resins will be adjusted to ± 5°C from ambient room temperature, as measured at the beginning of the experiment. This temperature will be monitored throughout the test.
2. The column will be held vertically, with the tubing and valves arranged as shown in Fig. 1 below. The glass beads will be added to fill approximately 50mm of the bottom of the column.

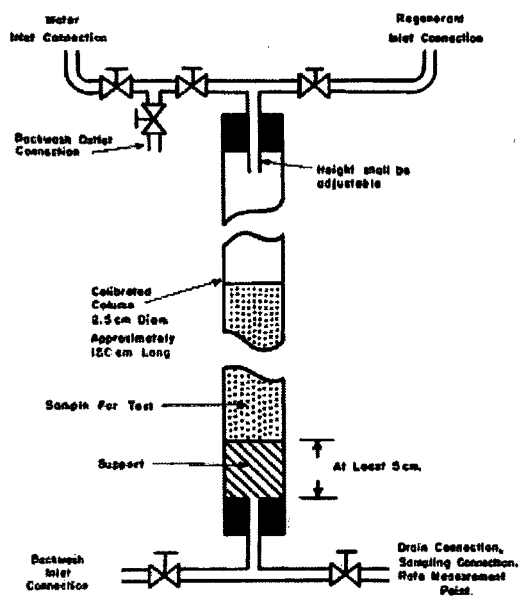

Figure 1: Typical Arrangement of Apparatus for Pretreatment of Ion Exchange Materials

3. The column will be filled half with deionized water. Sufficient resin will be added to create a bed of approximately 750mm above the support material. The height of the resin and support material will be recorded.
4. The column will be backwashed with deionized water for 10 minutes at a flow rate sufficient to cause a 50% expansion in the volume of the bed. If the effluent is not clear after 10 minutes, the backwash will continue at the same rate until clear effluent is obtained.
5. The bed will be allowed to settle. Once the bed has settled, the column will be drained at a rate of 100ml per minute until the water level reaches 20mm above the top of the bed. The bed volume will be recorded.
6. Step 5 will be repeated 3 times, or until the volumes agree within ±5ml. This will be recorded as the bed volume.
7. The column will then be flushed with mine water at a rate of 0.33 ml per minute per ml of resin in the bed. This will be calculated following the determination of bed volume. A liquid head of no less than 50mm will be maintained above the resin bed during the test.
8. An approximate resin exhaustion time will be determined using Purolite's PureDesign simulation software. The breakthrough time estimated by the software will be confirmed using lab results once the test has been completed.
9. Samples will be collected every hour, and pH and temperature measurements will be recorded.
10. A 10 minute backwash will be performed using deionized water, as described in step 4. Only a single backwash will be performed. A regeneration cycle will then be performed by passing an agreed upon eluent through the resin. The respective flow rate and retention time may differ based on manufacturers recommendations. Following completion of the elution, deionized water will be flushed through the bed at a rate of approximately 100ml/minute until regeneration is complete. The resulting wash water will not be analyzed.
11. The type of regenerant and rate will be determined through conversations with the resin manufacturers.
12. Steps 4 through 10 will be repeated once more for a total of 2 regenerations.
13. Hourly samples will be archived in a temperature-controlled environment under proper chain-of-custody procedures. A series of representative samples taken at equal time intervals will be submitted for laboratory analysis, as described in the project scope. These results will be used to confirm the time exhaustion occurred, and further testing can be performed on the archived samples as necessary.
14. Further tests can be performed to determine the effect of different regenerants on resin performance if deemed necessary.
15. The resin will be screened through appropriately sized filtration media following regeneration to determine the volume of fines generated by osmotic shock.

1.3 Revision Log

Revision Number	Author	Description of Change (Section number)	Date
0	AMEC	Initial version of SOP 12	June 2013